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(Original Article)

Implement of Some Biocontrol Tactics as an Innovative Management Against Cucurbit Fly, *Dacus ciliatus* and Western Flower Thrips, *Frankliniella occidentalis* on Squash Crop

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Abstract

Squash is an important vegetable crop and infested by numerous pests. Both cucurbit fly, *Dacus ciliatus* (Loew) and western flower thrips, Frankliniella occidentalis (Pergande), were mainly pests in squash. Field experiment was implemented biocontrol tactics for controlling these pests on squash. The present results showed a significant effective between all sequentially spraying of six treatments with the untreated field of squash plant against *D. ciliatus* and *F. occidentalis* infestations during the two investigated fall seasons, 2021 and 2022. The highest *D. ciliatus* and *F. occidentalis* infestations on squash was obtained with the 4th program contained sequentially spraying of *Bacillus megaterium*, spinetoram and emamectin benzoate plus yeast and 2% honeybee, azadrachtin + 2% black honey and mineral oil and the untreated filed during two tested fall seasons. Contrariwise, the application of 5th and 6th programs that contained sequentially spraying of *B. megaterium*, spinosad bait hydrolyzed protein + kerosene soil drench, orange oil and azadrachtin + 2% black honey gave the best results in reducing *D. ciliatus* and *F. occidentalis* infestations on squash during two fall seasons. Squash production increased in all treatments compared with untreated field, but its highest value was 4475.62 kg/feddan during two seasons. Therefore, we could be concluded that the sequentially spraying of 5th and 6th programs gave the higher reduction of two pests on squash. Consequently, this study can used to have sound decisions for these pest managements on cucurbits specially squash in Egypt during fall cultivations.

Keywords: *Bio-control tactics, Dacus ciliatus, Frankliniella occidentalis, Pest management, Squash.*

Introduction

Squash crop, *Cucurbita pepo* L. (Cucurbitaceae) is an important vegetable crop, cultivated in both open fields and under greenhouses, infested by numerous phytophagous species (Abdallah *et al*., 2012). Both Cucurbit fruit fly, *Dacus ciliatus* (Loew) (Diptera: Tephritidae) and Western flower thrips (WFT),

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Frankliniella occidentalis (Pergande), (Thysanoptera: Thripidae), were mainly insect pests, have been infested squash crop. Dipteran Tephritidae family have over 4000 species (Fletcher, 1987), about of 250 species are economic species and widely distributed in temperate, tropical and sub-tropical regions around the world (Christenson and Foote, 1960). Cucurbit fruit fly, *D. ciliatus* was the main insect pest has been infested with many plant families such as Cucurbitaceae, Fabaceae, Malvaceae, Rosaceae, Solanaceae and Asclepiadaceae (Kapoor, 1989). It is actually serious pest of cucurbit plants in Africa and Asia (Vayssières *et al*., 2008), especially in Egypt (Fetoh, 2003). The Firstly registration of the pumpkin fly, *D. ciliates* in Egypt by Azab and Kira (1954) on cucurbitaceous plants. One of the main squash pests is the endemic and endangered cucurbit fruit fly, *D.* ciliates. Fetoh (2003) found that it had oscillatory appearance year after year in Egypt on squash crops. Fruits of Cucurbitaceae infested with *D. ciliatus* usually show signs of oviposition punctures around which necrosis can occur. In severe infestations, the fruit may collapse, leaving only the skin of fruit (El Nahal *et al*., 1971).

Detection and monitoring systems generally based on strong olfactory attractant agents and control methods was also based on the attraction efficiency (Koyama *et al*., 2004). In particular, the attraction of this pest to cucurbit plant is usually related to volatile phytochemicals (Aluja and Mangan 2008), especially in specificity pest to their plant hosts as oligophagous, *D. ciliatus*. A little available information about the chemical ecology of *D. ciliates* was stated, and no attractant agents had been identified for this insect pest, in addition, numerous types of olfactory attractants for fruit fly pests such as plant kairomones, para-pheromones including volatiles derived from host plant or nonhost plant species, food lures as well as hydrolyzed protein sex pheromones (Metcalf, 1990; Jang and Light, 1996). For survival and maturity, fruit flies require to sugars and proteins as food sources (Mazzon *et al*., 2008), so that, fruit flies are strongly attracted by protein and sugar baits (Capuzzo *et al*., 2005; Estes, 2009). The principal of *D. ciliates* was based on protein bait control, therefore, Partial spray of spinosad bait pesticide on cucumber and squash to suppress of *D. ciliates*. Spinosad bait 0.024% CB, a partial spray, showed a good candidate for this pest attractant than the utilized of spinosad 24% SC, means that, *D. ciliates* was more sensitive and attractive to this baited active ingredient (Rizk, 2010). Also, the implementing of spinosad-based bait was effective to reduce in *Bactrocera cucurbitae* infestations (Delpoux and Deguine, 2015).

Numerous toxicological studies for different types of the sprayed insecticides as organophosphate and pyrethroid were conducted for controlling of *D. ciliatus* (Maklakov *et al*., 2001; Nestel *et al*., 2019). Moreover, spraying of organophosphate as dimethoate, chlorpyrifos ethyl and malathion active ingredients, carbamate as fenobucarb and pyrethroid as α-cypermethrin, deltamethrin and cypermethrin were used against fruit flies, *Dacus* spp. on cucurbits (Badji *et al*., 2001). On other fruit species, Al-Soltany *et al*. (2020) evaluated bifenthrin (pyrethroid) in normal and nanoparticles formulation against *D. frontalis* in cucumber crops. To reduce adult emergence, soil drench applications by systemic pesticides, spinetoram, spinosad, diazinon, lambdacyhalothrin, permethrin and tefluthrin were applied for controlling of tephritid flies, *Ba. cucurbitae*, *Ba. dorsalis* and *Ceratitis capitata* (Stark and Vargas, 2009; Stark *et al*., 2014). The garlic extracts against *D. ciliatus* contained 99.98% of garlic juice acting as a garlic barrier was proved harmless with a good, covered canopy and effectively repelled the insect pests.

Western flower thrips (WFT), *F. occidentalis* was a major horticulture pest (Kirk and Terry, 2003). It was Firstly recorded on vegetable crops in the Mediterranean region in Turkey by Tunc and Gocmen (1995), and rapidly spread on different crop types as squash (Hanafy, 2015), pepper (Teulon *et al*., 2014) and bean (Muvea *et al*., 2014). *F. occidentalis* has become an important insect pest caused injurious flower damages on squash crop (Hanafy, 2015). Additionally, it not only caused damages by sucking, but also indirectly by transmitting viral diseases as well as tomato spotted wilt virus and necrotic spot wilt virus to several crops (Elimem *et al*., 2014; Khalifa *et al*., 2021). *F. occidentalis* is small size, highly reproductive and rapidly spread causing highly infestation (Cloyd, 2009).

In a severe infestation of this thrips, the appropriate thrips management was applied by multiple applications of pesticides (Bethke *et al*., 2010). In Egypt, Hanafy (2015) used spinosyn, carbamate and neonicotinoid pesticide groups for controlling of *F. occidentalis* on cucumber plants. Multi apply of synthetic insecticides led to a resistance against many pesticide groups (Demirozer *et al*., 2012). The resistance had been stated for neonicotinoids (Minakuchi *et al*., 2013), organophosphorus (Robb *et al*., 1995), and pyrethroids and avermectin (Immaraju *et al*., 1992) insecticide groups by *F.* occidentalis.

Challenges in sustainable squash development are finding methods to manage squash-damaging insect pests without side effect on beneficial organisms as pollinators, because squash plant is highly pollinator-dependent crop. While traditional insecticides, provide control of these pests, can also affect pollinators (Obregon *et al*., 2022). Also, the pesticide residue and toxicity problems on marketable squash crops, towards biocontrol agents and environmental contamination, generated to need alternative methods for controlling of WFT and cucurbit fly. Demand for alternative insect pest management strategies for both pests of squash continue to increase in Egypt. Therefore, the current study aim to find the suitable of the implemented six biocontrol programs to manage the cucurbit fruit fly, *D. ciliatus* and western flower thrips, *F. occidentalis* based on the infestation monitoring to develop and implement a novel decision support system to control these pests.

Materials and Methods

Field experiment was carried out in a private farm at El-shahid Fekri village (30.68322194085885° N, 31.065906478816103° E), Birket El-Saba Province, Menofia, Egypt, during two successive fall seasons of 2021 and 2022. Squash seeds were sown on 15th august in both tested seasons. The experimental area of squash crop, Sakata variety was 700 m^2 divided into 7 plots. Each plot was considered to investigate a management control program.

Table 1. Applied control programs for *D. ciliatus* and *F. occidentalis* management on squash during fall seasons 2021 and 2022

Program	Treatments	Trade name	Date of application	Application rate
1st Program	Sequentially spraying of			
	-Bacillus megaterium	Bio Arc 6% WP	15th Sept.	250 g/100 liters
	-Spinosad + yeast	Tracer 24%SC + Local yeast	22nd Sept.	500 cm +250 g/100 liters
	-Jojoba oil + dispersal agent	Top-healthy 60%EC	11th Oct.	400 cm+ 500 cm/100 liters
	-Sulfur	Solfan KZ 70% SC	25th Oct.	200 cm/100 liters
	-Spinosad + yeast	Tracer 24%SC+Local yeast	2nd Nov.	500 cm +250 g/100 liters
	-Jojoba oil + dispersal agent	Top 60%EC	15th Nov.	400 cm+ 500 cm /100 liters
2nd Program	Sequentially spraying of			
	-Bacillus megaterium	Bio Arc 6% WP	15th Sept.	250 g /100 liters
	-Spinosad	Tracer 24%SC	22nd Sept.	500 cm /100 liters
	-Capsicum oleoresin 7.6%+garlic oil 23.4%+55% canola oil	Captivaprim 86% SC	11th Oct.	100 cm/100 liters
	-Jojoba oil	Top-healthy 60%EC	25th Oct.	400 cm /100 liters
	-Spinosad	Tracer 24%SC	2nd Nov.	500 cm /100 liters
	-Capsicum oleoresin 7.6%+garlic oil 23.4%+55% canola oil	Captivaprim 86% SC	15th Nov.	100 cm /100 liters
3rd Program	Sequentially spraying of			
	-Bacillus megaterium	Bio Arc 6% WP	15th Sept.	250 g /100 liters
	-Emamectin benzoate + yeast + 2% honeybee	Speedo 5.7% WG + Local yeast + Honeybee	22nd Sept.	100 g + 250 g + 2L /feddan
	-Azadrachtin + 2% black honey	Neemix 4.5% EC + black honey	11th Oct.	75 cm +2L /100 liters
	-Mineral oil	KZ oil 95% EC	25th Oct.	1L/100 liters
	-Emamectin benzoate + yeast + 2% honeybee	Speedo 5.7% WG + Local yeast + Honeybee	2nd Nov.	100 g + 250 g + 2L /feddan
	-Azadrachtin + 2% black honey	Neemix 4.5% EC + black honey	15th Nov.	75 cm +2L /100 liters
4th Program	Sequentially spraying of			
	-Bacillus megaterium	Bio Arc 6% WP	15th Sept.	250 g/100 liters
	-Spinetoram+ yeast + 2% honeybee	Rediant 12% SC+ Local yeast + Honeybee	22nd Sept.	50 cm + 250 g + 2L/100 liters
	Emamectin benzoate + yeast + 2% honeybee	Speedo 5.7% WG + Local yeast + Honeybee	11th Oct.	100 g + 250 g + 2L/feddan
	-Azadrachtin + 2% black honey	Oikas 3.2% EC + black honey	25th Oct.	100 cm + 2L/100 liters
	-Spinetoram+ yeast + 2% honeybee	Rediant 12% SC+ Local yeast + Honeybee	2nd Nov.	50 cm + 250 g + 2L /100 liters
	-Mineral oil	KZ oil 95% EC	15th Nov.	1L /100 liters
5th Program	Sequentially spraying of			
	-Bacillus megaterium	Bio Arc 6% WP	15th Sept.	250 g /100 liters
	-Spinosad Bait hydrolyzed protein + Kerosene soil drench	Conserve 0.024% CB +Kerosene soil drench	22nd Sept.	500cm (Full spray)+ 10 L soil drench/ feddan
	-Orange oil (d-limonene)	Prev-AM 6% SL	11th Oct.	400 cm /100 liters
	-Spinosad Bait hydrolyzed protein + Kerosene soil drench	Conserve 0.024% CB +Kerosene soil drench	25th Oct.	500cm (Full spray) + 10 L soil drench/ feddan
	-Orange oil (d-limonene)	Prev-AM 6% SL	2nd Nov.	400 cm /100 liters
	-Azadrachtin + 2% black honey	Neemix 4.5% EC	15th Nov.	75 cm +2L /100 liters
6th Program	Sequentially spraying of			
	-Bacillus megaterium	Bio Arc 6% WP	15th Sept.	250 g /100 liters
	-Spinosad Bait hydrolyzed protein + Kerosene soil drench	Conserve 0.024% CB +Kerosene soil drench	22nd Sept.	1L (Full spray) + 10 L soil drench/ feddan
	-Orange oil (d-limonene)	Prev-AM 6% SL	11th Oct.	400 cm /100 liters
	-Spinosad Bait hydrolyzed protein + Kerosene soil drench	Conserve 0.024% CB +Kerosene soil drench	25th Oct.	1L (Full spray) + 10 L soil drench/ feddan
	-Orange oil (d-limonene)	Prev-AM 6% SL	2nd Nov.	400 cm /100 liters
	-Azadrachtin + 2% black honey	Neemix 4.5% EC	15th Nov.	75 cm +2L /100 liters
Control	Check (control)	Without treatement		——

Six programs for management control of the cucurbit fruit fly, *D. ciliatus* and the western flower thrips, *F. occidentalis* used a spray of biocontrol agents to be compared with untreated control (Table 1). All treatments in the experimental area in a random complete block design and each treatment had three replicates. Comparisons between 6 programs of the selected biopesticides against *D. ciliatus* and *F. occidentalis* and untreated control (check) were conducted during two successive seasons, 2021 and 2022. The date and rate of the treatment applications were used as that tabulated in Table (1). The applied pesticides were calibrated by using Hand-Held compression sprayer before the application. The check plot (without treated squash plot) was sprayed by water.

Weekly sample of 10 squash flowers from each replicate were randomly inspected to record the mean numbers of thrips individuals (adults and nymphs/squash flower) on 11st October during both two seasons till the end of experiments. Inspection of WFT individuals per squash flowers was carried out by using inspection white plate (23 cm width × 33 cm length). This inspection plate was sprayed by water to avoid thrips escaping.

Concerning of cucurbit fruit fly, *D. ciliatus*, 50 squash fruits from each replicate were randomly weekly selected to determine the mean numbers of healthy and infested fruits per 50 squash fruits at the beginning of fruiting stage after one month from plantation during both two seasons till the end of harvest time. For yield comparison, the total squash production per ton feddan^{-1} was determined for all management programs during two investigated fall seasons, 2021 and 2022. Statistical analysis : The obtained results were statistically analyzed using SAS v 9.3 (SAS, 2003) including f-test, t-test and simple correlation and partial regression analyses. The least significant differences (LSD) were used to compare between the obtained means at 5% levels of probability.

Results

Impact of different control programs on *D. ciliatus* infestations on squash fruit during two fall seasons 2021 and 2022

The infestations of *D. ciliatus* (mean no. of the infested squash fruits) on squash plant during the two investigated fall seasons, 2021 and 2022 were studied under six control programs, and it was showed in Table (2). A non-significant effective was recorded between all sequentially spraying of six treatments but all of them was showed a high significant with the untreated check (control) of squash plant. In view of the obtained results, the mean no. of healthy fruits/ 50 fruits was high value with both two selected control programs, 5 and 6, and then followed by the 2nd program being 16.92, 16.42 and 15.92 fruits during fall season, 2021, respectively, but these values were increased during fall season, 2022 being 26.75, 26.92 and 27.17 healthy fruits per 50 squash fruits with the 2nd, 6th and 5th programs. Also, the same arrangement was reported during the two seasons altogether with total healthy fruit percentage was 43.83, 43.17 and 43.08 % with the 5th, 6th and 2nd control programs, respectively. On the other direction, a low value of healthy squash fruits was obtained with the 4th control program being value of 19.54 healthy fruits per 50 squash fruits with healthy percentage being 39.08% during both two tested seasons. The untreated check (control) of squash crop was not reached to 7 healthy fruits /50 squash fruits with healthy fruit percentage was 8.08% during two tested seasons, 2021 and 2022 (Table 2). In our study, the infested of squash fruits caused by *D. ciliatus* adults was slightly lower between both of 5th and 6th program and the other tested selected programs when compared between them. The mean number of infested squash fruits was higher throughout the 1st fall season than the 2nd fall season which its value was extended from 33.08 - 36.00 and 23.08-24.92 fruits/ 50 squash fruits, respectively. The total mean no. of infested fruits was recorded the lowest values (28.08 and 28.42 fruits/ 50 fruits) with 56.17 and 56.83% fruit infestation during two seasons for 5th and 6th control programs, respectively (Table 2). The highest *D. ciliatus* infestations on squash fruit was obtained with the 4th program (60.92%) (sequentially spraying of *B. megaterium*, spinetoram+ yeast+ 2% honey bee, emamectin benzoate+ yeast+ 2% honey bee, azadrachtin+ 2% black honey, mineral oil) and the untreated check (control)(91.92%) during two fall seasons 2021 and 2022.

Table 2. Impact of the selected six control programs on *D. ciliatus* infestations on squash fruits during two fall seasons 2021 and 2022

Treatment programs	Mean no. of healthy fruits/ 50 fruits			Healthy fruits %	Mean no. of infested fruits/ 50 fruits			Fruit infestation %
	2021	2022	Mean		2021	2022	Mean	
1st Program	14.58 a ±0.24	25.92 a ±1.68	20.25 a ±0.72	40.5	35.42 b ±1.97	24.08 b ±2.36	29.75 b ±2.17	59.5
2nd Program	15.92 a ±2.26	27.17 a ±1.83	21.54 a ±2.04	43.08	34.08 b ±2.36	22.83 b ±2.21	28.46 b ±2.29	56.92
3rd Program	14.42 a ±2.55	26.08 a ±3.51	20.25 a ±3.03	40.5	35.58 b ±3.22	23.92 b ±2.84	29.75 b ±3.03	59.5
4th Program	14.00 a ±1.73	25.08 a ±2.36	19.54 a ±2.04	39.08	36.00 b ±2.31	24.92 b ±2.26	30.46 b ±2.29	60.92
5th Program	16.92 a ±3.99	26.92 a ±3.42	21.92 a ±3.70	43.83	33.08 b ±2.93	23.08 b ±4.09	28.08 b ±3.51	56.17
6th Program	16.42 a ±2.55	26.75 a ±2.74	21.58 a ±2.65	43.17	33.58 b ±2.07	23.25 b ±1.88	28.42 b ±1.97	56.83
Control	1.5 b ±0.40	6.58 b ±1.49	4.04 b ±0.95	8.08	48.5 a ±2.60	43.42 a ±3.13	45.96 a ±2.86	91.92
F value	5.39	8.64	7.25	—	4.48	7.33	5.90	—
LSD	6.998	7.732	7.222		7.68	8.40	8.01	

Means signed by same letter were not significant in the same column at 0.05 level of probability.

Generally, the application of 5th and 6th programs (sequentially spraying of *B. megaterium*, spinosad bait hydrolyzed protein + kerosene soil drench, orange oil (d-limonene) and Azadrachtin + 2% black honey), gave the best results in reducing the cucurbit fruit fly, *D. ciliatus* infestations on squash crop throughout two fall seasons 2021 and 2022.

Impact of different control programs on *F. occidentalis* infestations on squash plant during two fall seasons, 2021 and 2022

The obtained results in Table (3) were reported that the *F. occidentalis* population recorded 3 peaks on 2nd, 21st Nov and 4th Dec. 2021 in all tested treatments. While these peaks were moved for one week during the second season, 2022 in which the peaks were noticed on 25th Oct. 15th and 27th Nov. 2022. During first season, the highest infestation of *F. occidentalis* was 6.13, 4.73, 4.4, 4.33, 3.8, 2.53 and 2.33 nymphs and adults per flower with the unsprayed treatment (control), 1st, 4th, 3rd, 2nd, 6th and 5th programs on 2nd Nov. 2021, respectively. Similarly, the total mean number of *F. occidentalis* infestations had the same arrangement order with mean extended between 1.34 - 3.27 nymphs and adults/ flower during fall season, 2021. Throughout the second season, 2022, an alike obtained data was reported as in the first season, but the highest peak was detected on 25th Oct., with the overall mean of *F. occidentalis* infestations was slightly lower than the 1st season which extended between 0.77- 2.73 nymphs and adults/ flower during fall season, 2022 (Table 3).

Table 3. Impact of the selected six control programs on *F. occidentalis* infestations on squash plant during two fall seasons, 2021 and 2022

Inspection dates	Mean no. of *F. occidentalis* nymphs & adults/ flower													
	Treated programs during season 2021							Treated programs during season 2022						
	Control	1st Program	2nd Program	3rd Program	4th Program	5th Program	6th Program	Control	1st Program	2nd Program	3rd Program	4th Program	5th Program	6th Program
11st Oct.	**1.47** ±0.37	**1.40** ±0.44	**1.13** ±0.44	**1.07** ±0.43	**1.13** ±0.37	**1.07** ±0.34	**1.00** ±0.46	**0.93** ±0.32	**0.87** ±0.42	**0.73** ±0.41	**0.53** ±0.38	**0.60** ±0.32	**0.47** ±0.27	**0.47** ±0.40
18th Oct.	**2.27** ±0.28	**1.60** ±0.39	**1.33** ±0.41	**1.07** ±0.30	**1.40** ±0.51	**1.00** ±0.32	**0.73** ±0.30	**1.73** ±0.36	**1.07** ±0.38	**0.80** ±0.38	**0.53** ±0.22	**0.87** ±0.49	**0.40** ±0.24	**0.20** ±0.14
25th Oct.	**6.00** ±1.15	**3.33** ±0.79	**1.93** ±0.62	**3.07** ±0.87	**3.73** ±1.27	**2.00** ±0.39	**2.27** ±0.46	**5.67** ±1.56	**4.27** ±1.51	**3.33** ±1.04	**3.87** ±1.54	**3.93** ±1.35	**1.80** ±0.52	**2.07** ±1.11
2nd Nov.	**6.13** ±1.45	**4.73** ±1.44	**3.80** ±0.96	**4.33** ±1.47	**4.40** ±1.27	**2.33** ±0.46	**2.53** ±1.08	**5.47** ±1.26	**2.80** ±0.87	**1.40** ±0.64	**2.53** ±0.93	**3.20** ±1.34	**1.40** ±0.40	**1.73** ±0.48
9th Nov.	**5.47** ±0.91	**2.27** ±0.34	**1.60** ±0.24	**3.33** ±0.87	**2.93** ±0.73	**1.20** ±0.33	**1.40** ±0.27	**4.87** ±0.93	**1.73** ±0.41	**1.07** ±0.23	**2.80** ±0.94	**2.40** ±0.80	**0.67** ±0.27	**0.87** ±0.24
15th Nov.	**3.13** ±0.42	**2.00** ±0.28	**1.60** ±0.34	**2.27** ±0.50	**2.53** ±0.75	**1.33** ±0.30	**1.40** ±0.31	**5.20** ±1.14	**2.93** ±1.31	**1.80** ±0.53	**3.20** ±1.10	**3.47** ±0.87	**1.27** ±0.45	**1.67** ±0.43
21st Nov.	**5.73** ±1.05	**3.47** ±1.26	**2.33** ±0.47	**3.73** ±1.03	**4.00** ±0.76	**1.87** ±0.42	**2.20** ±0.38	**2.60** ±0.49	**1.47** ±0.27	**1.07** ±0.33	**1.73** ±0.52	**2.00** ±0.79	**0.73** ±0.27	**0.87** ±0.27
27th Nov.	**1.67** ±0.36	**1.27** ±0.28	**1.20** ±0.31	**1.07** ±0.30	**0.93** ±0.28	**0.93** ±0.27	**1.00** ±0.29	**2.40** ±0.72	**2.13** ±0.69	**2.07** ±0.64	**1.87** ±0.76	**2.27** ±0.72	**1.13** ±0.27	**1.53** ±0.31
4th Dec.	**2.93** ±0.67	**2.67** ±0.63	**2.60** ±0.58	**2.40** ±0.74	**2.80** ±0.66	**1.73** ±0.25	**2.07** ±0.30	**1.13** ±0.36	**0.73** ±0.23	**0.67** ±0.25	**0.53** ±0.22	**0.40** ±0.16	**0.53** ±0.22	**0.47** ±0.19
11th Dec.	**1.67** ±0.29	**0.93** ±0.30	**0.87** ±0.29	**1.07** ±0.32	**1.13** ±0.32	**1** ±0.29	**1.2** ±0.31	**1.13** ±0.24	**0.4** ±0.19	**0.33** ±0.16	**0.53** ±0.24	**0.6** ±0.25	**0.4** ±0.19	**0.67** ±0.25
18th Dec.	**1.47** ±0.24	**1.33** ±0.27	**0.8** ±0.28	**1.2** ±0.26	**1.13** ±0.29	**0.93** ±0.30	**1** ±0.28	**0.93** ±0.21	**0.8** ±0.22	**0.27** ±0.12	**0.67** ±0.19	**0.6** ±0.21	**0.33** ±0.19	**0.47** ±0.17
25th Dec.	**1.27** ±0.38	**1.07** ±0.32	**0.87** ±0.29	**0.8** ±0.28	**0.73** ±0.28	**0.73** ±0.28	**0.73** ±0.28	**0.73** ±0.34	**0.53** ±0.24	**0.33** ±0.16	**0.27** ±0.12	**0.4** ±0.21	**0.13** ±0.09	**0.2** ±0.11
Mean	**3.27 a**	**2.17 b**	**1.67 b**	**2.12 b**	**2.24 b**	**1.34 b**	**1.46 b**	**2.73 a**	**1.64 b**	**1.16 b**	**1.59 b**	**1.73 b**	**0.77 b**	**0.93 b**
± SE	**± 0.57**	**± 0.34**	**± 0.26**	**± 0.36**	**± 0.38**	**± 0.15**	**± 0.18**	**± 0.57**	**± 0.34**	**± 0.26**	**± 0.36**	**± 0.38**	**± 0.15**	**± 0.18**
F value				**3.52**							**3.55**			
LSD				**0.9737**							**0.9782**			

Means signed by same letter were not significant in the same row at 0.05 level of probability in each season.

As well as in *D. ciliatus* infestation, the same order arrangement was reported in all investigated control programs against *F. occidentalis* infestations, a non-significant analysis was recorded between the choice six control programs, but it was a significant effect with the unsprayed treatment during both tested two seasons (Table 3). Also, the two tested programs, 5th and 6th were harbored the lowest infestations being 1.34 and 1.46 nymphs and adults/ flower during 2021 and 0.77 and 0.93 nymphs and adults/ flower during 2022, respectively. However, the 4th control program and unsprayed treatment was harbored a high infestation being 2.24 and 3.27 nymphs and adults per flower during 2021 and 1.73 and 2.73 nymphs and adults/ flower during 2022, respectively, followed by both choice treatments, 1st and 3rd programs. In view of all treatments, the sequentially spraying of B. *megaterium*, spinosad bait hydrolyzed protein + kerosene soil drench, orange oil (d-limonene) and azadrachtin + 2% black honey with the dose of application as that reported in Table (1) in the 5th and 6th programs caused the higher reduction of F. occidentalis individuals on squash plant during the two fall seasons 2021 and 2022 than other tested control programs.

Impact of the six control programs on squash yield during fall seasons, 2021 and 2022

Data in Table (4) was reported that the sequentially spraying of control program contained *B. megaterium*, spinosad bait hydrolyzed protein + kerosene soil drench, orange oil (d-limonene) and azadrachtin + 2% black honey in the 5th and 6th programs gave significantly highest squash production than other control program and untreated check field (control field) in the two tested seasons, 2021 and 2022.

The highest squash fruit production was 2976.38 and 5974.85 kg/feddan throughout 2021 and 2022, respectively, with overall mean yield being 4475.62 kg/feddan during altogether tested fall seasons. However, untreated check field (control field), the 4th and 1st programs were received the lowest squash fruit production being 1234.82, 1466.85 and 1468.50 kg/feddan during 2021 and 2491.73, 2955.78 and 2959.09 kg/feddan during 2022 seasons, respectively. The overall fruit production was 1863.28, 2211.31 and 2213.80 kg/feddan with untreated check 4th and 1st programs, respectively (Table 4). Accordingly, the obtained data clearly indicated that the 5th control program may be the best program for controlling cucurbit fruit fly, *D. ciliatus* and western flower thrips, *F. occidentalis* on squash crop, Sakata variety at Menofia governorate, Egypt. A through the present study, it is clear that the squash fruit production increased in all control programs when compared with untreated check field (control field).

Table 4. Effect of different control programs on squash yield during two fall seasons

Treated programs	Production weight (kg)/feddan		
	Fall season, 2021	Fall season, 2022	Mean
1st Program	1468.50 c	2959.09 bc	2213.80 c
	±322.16	±265.05	±293.61
2nd Program	1662.26 bc	3346.59 bc	2504.42 bc
	±124.90	±142.37	±133.64
3rd Program	1534.56 c	3091.20 bc	2312.88 bc
	±26.60	±1611.50	±819.05
4th Program	1466.85 c	2955.78 bc	2211.31 c
	±263.15	±228.50	±245.83
5th Program	2976.38 a	5974.85 a	4475.62 a
	±559.17	±216.42	±387.79
6th Program	2220.70 b	4463.47 ab	3342.08 b
	±266.12	±209.85	±237.98
Control	1234.82 c	2491.73 c	1863.28 c
	±84.54	±226.16	±155.35
F value	7.83	3.55	6.66
LSD	873.09	1946.1	1183.9

Means signed by same letter were not significant in the same column at 0.05 level of probability.

Concerning the relationship between squash yield and D. *ciliatus* and F. *occident alis* infestations, data is recorded in Table (5) conducted a significant negative relation between squash production and the population of F. *occidentalis* nymphs and adults/ flower on squash crop in which the increasing of F. *occidentalis* infestations will decrease the yield. While a non-significant negative relationship between squash production and D. *ciliatus* infestations / 50 fruits on squash production throughout the two investigated seasons 2021 and 2022.

The correlation coefficient (r) was registered its highest value (- 0.789) with the probability 0.035 in case of squash production and *F. occidentalis* infestation. However, it was - 0.502 with the probability 0.251 between *D. ciliatus* infestation and squash yield (Table 5). Accordingly, the increasing of *D. ciliates* and *F. occidentalis* infestations will decrease the squash yield during altogether two investigated seasons, 2021 and 2022.

Table 5. Correlation matrix between *D. ciliates* and *F. occidentalis* infestations with squash yield throughout the two tested seasons, 2021 and 2022

Parameters		Squash yield	*Dacus ciliatus* infestation	*F. occidentalis* population
Squash yield	r	1.00	- 0.502	- 0.789
	P	——	0.251	0.035
Dacus ciliatus infestation	r	- 0.502	1.00	0.896
	P	0.251	——	0.006
F. occidentalis population	r	- 0.789	0.896	1.00
	P	0.035	0.006	——

r = Correlation coefficient P = Probability at 0.05 level

Discussion

The present data showed that the cucurbit fly, *D. ciliatus* was a high infestation % during the two investigated fall seasons, 2021 and 2022 ranged 56.17- 60.92 % in all treatments but it was reached up to 90 % in untreated squash crops. Similarly, Dhillon *et al*. (2005) observed that the losses percentage extended between 30 to 100% depending on the season. Also, the cucurbit fruit fly, *D. ciliatus* remains active throughout the year on numerous hosts, and it was considered the mainly pest of cucurbits, as it caused considerable yield losses (Mohammed, 2008). This state was similar to as those findings in Egypt. Also, the infestation percentage on fruits of cucumber was very high up to 100% in all treatment at the beginning of fruit stage during the first week of October 2015 (Al Shalchi and Al-Jorany, 2018). Moreover, Jannoune (1946) estimated that the *D. ciliatus* damage was to be 50% in sweet and mandarin oranges in Eritrea. However, in India, Singh *et al*. (2000) recorded that the fruit damage was 31.27% in bitter gourd and 28.55% in watermelon caused by *D. ciliatus*. Contrariwise, the infestation of *Dacus* spp. on squash crop ranged from zero to 1.17% at Aburoof region, Sudan (Mohammed, 2008). The obtained data also illustrated that the *D. ciliatus* infestation concentrated during fall season extended between October to December, as well as those findings by Mohammad (2022) and Paydar *et al*.

(2020), they found that the highest insects' attraction was found during last week of October throughout fall season.

In the present results, a non-significantly effective was recorded between all sequentially spraying of six treatments but all of them was showed a high significant with the untreated check (control) of squash plant against *D. ciliatus* infestations during the two tested fall seasons. The application of 5th and 6th programs that contained sequentially spraying of spinosad bait hydrolyzed protein + kerosene soil drench, orange oil (d-limonene) and azadrachtin bait 2% black honey gave the best results in reducing *D. ciliatus* infestations on squash crop during the two tested fall seasons. These obtained results were similar to those findings by Basit *et al*. (2018), they found the *Bactrocera cucurbitae* (Diptera: Tephritidae) on bitter gourd (*Momordica charantia* L.) was reported minimum fruit fly infestation (6%) and high marketable yield (855 g/bed) when this crop was treated by spinosad and then followed by blue colored refractive sheets. Few studies have been determined the efficiency of bait sprays against *D. ciliatus* in Egypt which it was concentrated only on spinosad bait with protein. The toxic effect of spinosad is a stomach poison with some contact activity, which is effective against various Diptera and Lepidoptera (Salgado 1998; Jacquet *et al*., 2006). Spinosad, an active ingredient, has not affected on *D. ciliatus* adults, so that, it must be baited on food substances of adults as proteins or polysaccharides. In this study, any selected active ingredients baited with protein and honeybee or black honey solution was the main control factor was affected *D. ciliatus* on squash plant. Similarly, Nishida (1980) conducted that a bait spray provided a source of protein needed for male and female flies to complete their sexual maturity. Moreover, spinosad-based protein bait was used for attracting of *Bactrocera cucurbitae*, *D. ciliatus* and *D. demmerezi* adults (Diptera: Tephritidae) in Reunion Island by Deguine *et al.* (2012). The *D. ciliatus* pupation usually takes place on ground inside the upper layer of soil (Malihi, 1998). Therefore, the lowest infestation was observed with 5th and 6th control programs contained kerosine soil drench in obtained results that it may be reduced the *D. ciliatus* pupation in soil.

The principal of control technique in the present study is the food sources behind the bioactive ingredients (spinosad, emamectin benzoate, azadrachtin, orange oil, jogoba oil, *Capsicum oleoresin* extract, garlic oil, canola oil and mineral oil) that needed for eggs laying by female flies such as hydrolyzed protein, beer yeast, sugar (honeybee and black honey) (food bait control). As like as numerous authors such as Fetoh and Asiry (2012), they suggested that the plant extract of *Melia azedarach* leaves was a sustainable larvicidal pesticide for controlling *D. ciliatus*. Additionally, the control of *D. frontalis* on cucurbits bait with protein hydrolysate was conducted by (Ba-Angood, 1977) on watermelon and sweet melon plants. The partial spray of the bio-insecticide spinosad bait hydrolyzed protein on cucumber and squash against the lesser pumpkin fly, *D. ciliates* was applied by Rizk (2010). On the other hand, Maklakov *et al.* (2001) found that pyrethroids had more potential activity for controlling *D. ciliatus* than organophosphate insecticides. Generally, in our study, we can be concluded that the controlling *D. ciliatus* based on both of insecticide and attractant food source together, also, in future, we can be made combination between the previously program with both of colour and pheromone traps, as well as those was conducted by Paydar *et al*. (2020), they used various attractants including sugar beet molasses, hydrolyzed protein, ammonium acetate solution, apple vinegar, beer yeast, ammonia lure and *Dacus* pheromone for *D. ciliatus* in Iran. Nestel *et al*. (2004) evaluated a bait suspension including spinosad as the toxic active ingredient based on 1% yeast hydrolysate with 10% sucrose as phagostimulant for *D. ciliatus* adults. They obtained 80 to 100% mortality with a high concentrated bait. Moreover, Mohammad (2022) was used yellow sticky trap for the attractant of this pest, who reported that adults were more attracted to yellow trap than green and red color sticky traps with mean being 5 insects/ trap.

In view of present results, the infestation of *F. occidentalis* was 0.77 and 3.27 individuals in each squash flower, similarly, Hua *et al*. (2011) found an average of 13-15, 5.7-24 and 0.4-5 western flower thrips/flower in squash, cucumber and watermelon in China. Also, Kakkar *et al.* (2012) observed low numbers per flower of *F. occidentalis* on squash crops in south Florida.

As well as in *D. ciliatus* infestation, the same order arrangement was reported in all investigated treatments against *F. occidentalis* infestations. A through the present study, we could be concluded that the sequentially spraying of spinosad bait hydrolyzed protein, kerosene soil drench, orange oil (d-limonene) and azadrachtin bait black honey (2%) in the 5^{th} and 6^{th} programs gave the higher reduction of *F. occidentalis* infestations on squash plant. These obtained results in this study was agree with those findings by Hanafy (2015), who reported that spinosad 24% and spinetoram 12% in formulation of SC gave considerable results in reducing *F. occidentalis* density (67.13% 60.03% and after 14 days of treatment, respectively). In addition, the key management of WFT by pesticides can be initiated at the low infestation of *F. occidentalis* to avoid the pest overlapping, once it reaches to a high infestation; its' control is difficult (Cloyd, 2009 and Sanad and Hassan, 2019). In view of the results those obtained by Sanad and Hassan (2019), different 9 pesticides in 4 control programs as in present study were sprayed for controlling *F. occidentalis* stages in rotating insecticides, like as, Robb and Parrella, (1995) reported that the primary rule to prevent or reduce the WFT resistance from insecticide is the used of insecticide rotating. On the other hand, Kontsedalov *et al*. (1998) applied organophosphates, carbamate and pyrethroid against *F. occidentalis*. Moreover, Sanad and Hassan (2019) sprayed rotationally insecticides including sulfoxaflor 24% SC, imidacloprid 35% SC, acetamiprid 20% SP, azadirachtin 0.18% EC, amizatine 20% EC, chlorfenapyr 24% SC, mineral oil 98% EC and agricultural potassium soap 49% liquid.

For successfully integrated management of *F. occidentalis* on squash plant during fall season, the sequential spray of the selected insecticides from different chemical pesticide groups gave best reducing this pest to avoid a broad resistance range against insecticides for numerous chemical groups (Sanad and Hassan, 2019). Consequently, this study can be used to have sound decisions for western flower thrips, *F. occidentalis* management on cucurbit crops specially squash plant conservation in Egypt during two tested fall seasons 2021 and 2022.

A negative relationship was observed between both *D. ciliates* and *F. occidentalis* infestations and squash yield, the obtained data the increasing of these pests' infestations will decrease the squash production during altogether two investigated seasons, 2021 and 2022. Moreover, the squash fruit production increased in all six control programs when compared with untreated check field (control field) but its highest value was 4475.62 kg/feddan during both tested two seasons. Similarly, Pitan and Filani (2013) noticed that cucumber yield was higher by 50% in sprayed plots over the untreated plot in management of cucumber pests. In melon, Badji *et al*. (2001) found that production was 2 to 3 times more in the pesticide treatments compared with control or unsprayed plants. According to the previously mentioned discussion, data of this study represent a valuable contribution to improve the integrated pest management program (IPM) of both the cucurbit fly, *D. ciliatus* and the western flower thrips, *F. occidentalis* on cucurbit crops.

Conclusion

A through the present study, we could be concluded that the sequentially spraying of *B. megaterium*, spinosad bait hydrolyzed protein + kerosene soil drench, orange oil (d-limonene) and azadrachtin + 2% black honey in the 5th and 6th programs gave the higher reduction of *D. ciliatus* and *F. occidentalis* infestations on squash plant. Consequently, this study can be used to have sound decisions for cucurbit fruit fly, *D. ciliatus* and western flower thrips, *F. occidentalis* management on cucurbit crops specially squash plant conservation in Egypt during the two fall seasons 2021 and 2022. In future work, we need to make a combined of both plant extracts and bio pesticides baited feeding attractants with specific sex pheromone traps of *D. ciliatus* and *F. occidentalis* to suppression these mainly pests in cucurbits in Egypt.

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Author Contributions

All authors contributed to the putting of the idea, preparing and writing of the manuscript and conducting of data analysis. All authors contribute by 100% participation. all authors reading and approving the final manuscript.

Conflicts of Interest

All authors declare no conflict of interest.

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تطبيق بعض طرق المكافحة الحيوية كإدارة مبتكرة ضـــد ذبابة القرعيات ***Dacus ciliatus*** وتربس الأزهار الغربي ***Frankliniella occidentalis*** على محصول الكوسة

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الملخــص

يعتبر محصــول الكوســة من المحاصــيل القرعية الهامة ويصــاب بالعديد من الآفات. وتعد ذبابة المقات *Dacus ciliatus* وتربس الأزهار *الغربي* *Frankliniella occidentalis* من الآفات الرئيســية التي تصــيب الكوســة. وقد أجريت تجربة حقلية لتطبيق بعض طرق المكافحة الحيوية لإدارة الآفتين. وقد أظهرت النتائج وجود تأثير معنوي بين كل برامج المكافحة المختبرة مع المقارنة غير المعامل ضــد تلك الآفتين على الكوســة خلال موســمي الخريف 2021 و2022. وقد سُجلت أعلى نسبة إصابة بالآفتين مع البرنامج الرابع المختبر الذي يحتوي على رش متتابع لكل من *Bacillus megaterium*، Spinetoram وEmamectin benzoate محملين على خميرة بيرة + 2٪ عسل نحل، Azadrachtin + 2٪ عسل أسود وزيت معدني وكذلك المقارنة خلال موسمي الخريف المختبرة. وعلى العكس من ذلك، فإن برنامج المكافحة الخامس والســـادس لذبابة المقات وتربس الأزهــار الغربي الــذى يحتوي على رش متتــابع لكــل من *Bacillus megaterium*، Spinosad محمل مع بروتين متحلل + حقن كيروسين في التربة، زيت البرتقال و Azadrachtin + 2٪ عسل أسود أعطى أفضل خفض فى الإصابة بالآفتين على الكوسة خلال موسمي الخريف.و قد سُـــجلت أعلى إنتاجية مع كل المعاملات المختبرة مقارنة بإنتاجية المقارنة وكانت أعلى إنتاجية مع برنامج المكافحة الخامس المختبر بمتوسط 4475.62 كجم / فدان. ومن خلال النتائج المتحصل عليهـا أعطى البرنـامجين الخـامس والســـادس الـذي يحتوي على رش متتـابع من *Bacillus megaterium*، Spinosad محمل مع بروتين متحلل + حقن كيروســين في التربة، زيت البرتقال و Azadrachtin + 2٪ عســل أســود أعلى خفض في الإصـــابة على الكوســة وبالتالي يمكن أن نســتخدمهم لاتخاذ قرارات لعمل إدارة متكاملة لتلك الآفتين على المحاصـــيل القرعية خلال الزراعات الخريفية.

الكلمات الدالة: *مكافحة حيوية، ذبابة القرعيات، تربس الأزهار الغربي، إدارة الآفة، الكوسة*